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(54) SYSTEM AND METHOD FOR AUTOMATICALLY CONTROLLING A WORK VEHICLE DURING THE PERFORMANCE OF AN EARTHMOVING OPERATION

(57) A method for automatically controlling an operation of a work vehicle during the performance of an earthmoving operation may include receiving an input associated with initiating an automated dumping operation to allow a load of worksite materials contained by an implement of a lift assembly of the work vehicle to be released onto a dump pile. The method may further include determining a current vertical height of the dump pile based on data from at least one sensor and determining a dumping height of the implement for performing the dumping operation based on the current vertical height. Additionally, the method may include controlling an operation of the lift assembly to move the implement to the dumping height and then to pivot the implement from a load-carrying position to a loaddumping position to release the load of worksite materials onto the dump pile from the dumping height.

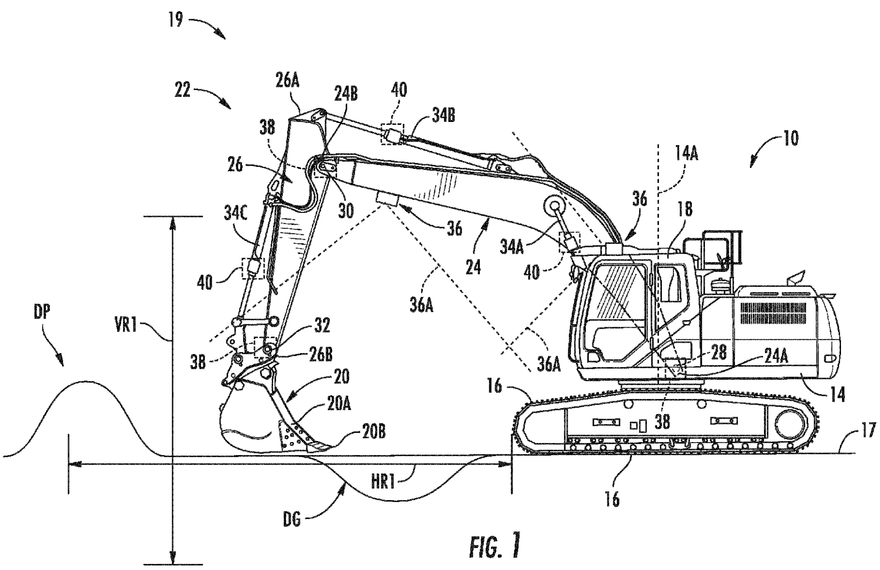

FIG. 1

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Description

FIELD OF THE INVENTION

[0001] The present disclosure relates generally to work vehicles, such as excavators and backhoes, and, more particularly to systems and methods for automatically controlling a work vehicle during the performance of an earthmoving operation, such as a dumping operation.

BACKGROUND OF THE INVENTION

[0002] A wide variety of work vehicles, such as excavators, loaders, shovels, bull-dozers, and/or the like, have been developed for performing various tasks of earthmoving operations, such as carrying loads, moving earth, digging, dumping, and/or the like, at a worksite. These work vehicles have lift assemblies including a boom and an implement pivotable relative to the boom, such as buckets, claws, and/or the like of varying sizes, which are selected based on the site and task requirements. A machine operator may control the operation of the work vehicle to perform the various worksite tasks. However, such tasks are often repetitive and time-consuming, which causes operator fatigue and high operating costs. As such, it is desirable to automate as much of the repetitive tasks as possible.

[0003] Particularly with dumping operations, the implement must be moved to a proper height for unloading worksite materials onto a dump pile at the worksite without causing interference between the implement and the dump pile as the dump pile grows. To solve this problem, control systems have been disclosed that attempt to account for growth of the dump pile by automatically linearly incrementing the height for unloading worksite materials for each subsequent dumping operation. However, the growth of dump piles is not linear. Therefore, such control systems move the implement excessively, which is less efficient and causes higher operating costs.

[0004] Accordingly, an improved system and method for automatically controlling a work vehicle during the performance of an earthmoving operation would be welcomed in the technology.

BRIEF DESCRIPTION OF THE INVENTION

[0005] Aspects and advantages of the invention will be set forth in part in the following description, or may be obvious from the description, or may be learned through practice of the invention.

[0006] In one aspect, the present subject matter is directed to a system for automatically controlling a work vehicle during the performance of an earthmoving operation. The system has a lift assembly including a boom and an implement coupled to the boom, with the implement being pivotable relative to the boom between a load-carrying position and a load-dumping position. The system further has at least one sensor supported relative to the lift assembly, where the at least one sensor is configured to generate data indicative of a vertical height of a dump pile located at a dump location within a worksite. Additionally, the system has a computing system communicatively coupled to the work vehicle and the at least one sensor. The computing system is configured to receive an input associated with initiating an automated dumping operation to allow a load of worksite materials contained by the implement to be released onto the dump pile at the dump location. The computing system is further configured to determine a current vertical height of the dump pile based at least in part on the data from the at least one sensor and to determine a dumping height of the implement for performing the dumping operation based at least in part on the current vertical height of the dump pile. Moreover, the computing system is configured to control an operation of the lift assembly to move the implement to the dumping height in response to receiving the input associated with initiating the dumping operation. Additionally, the computing system is configured to control an operation of the lift assembly to pivot the implement relative to the boom from the load-carrying position to the load-dumping position to release the load of worksite materials onto the dump pile from the dumping height.

[0007] The dump location may be spaced apart from a current dig location of the work vehicle in a horizontal direction across the worksite. The computing system may be further configured to determine a travel path for moving the implement between a starting point disposed at or adjacent to the current dig location to an ending point disposed at or adjacent to the dump location. The ending point may be positioned above the dump pile and at the dumping height. Controlling the operation of the lift assembly to move the implement to the dumping height may comprise controlling the operation of the lift assembly to move the implement along the travel path from the starting point to the ending point.

[0008] The dumping operation may be a first dumping operation. The computing system may be further configured to:

receive an input associated with initiating a subsequent automated dumping operation to allow a subsequent load of worksite materials contained by the implement to be released onto the dump pile at the dump location, subsequent to the first dumping operation;
determine an updated current vertical height of the dump pile after the first dumping operation based at least in part on the data from the at least one sensor;
determine an updated dumping height of the implement for performing the dumping operation based at least in part on the updated current vertical height of the dump pile;
control an operation of the lift assembly to move the implement to the updated dumping height in response to receiving the input associated with initiat-

ing the subsequent automated dumping operation; and

control an operation of the lift assembly to pivot the implement relative to the boom from the load-carrying position to the load-dumping position to release the subsequent load of worksite materials onto the dump pile from the updated dumping height.

[0009] The dumping height for the first dumping operation may be disposed at a first vertical offset above the dump pile. The updated dumping height for the subsequent dumping operation may be disposed at a second vertical offset above the dump pile. The first and second vertical offsets may be equal.

[0010] The at least one sensor may comprise at least one vision-based sensor configured to generate vision-based data indicative of the vertical height of the dump pile. The computing system may be configured to determine the current vertical height of the dump pile based at least in part on the vision-based data.

[0011] The at least one vision-based sensor may be further configured to generate vision-based data indicative of a fill-level of the implement. The input associated with initiating the automated dumping operation may be received in response to the fill-level of the implement being equal to or greater than a fill-level threshold.

[0012] The computing system may be further configured to:

determine a predicted height of the dump pile associated with adding the load of worksite materials to the dump pile based at least in part on the fill-level of the implement and the current vertical height of the dump pile; and

compare the predicted height of the dump pile to a height threshold for the dump pile,

[0013] The computing system may be configured to control the operation of the lift assembly to move the implement to the dumping height if the predicted height of the dump pile is less than the height threshold.

[0014] The at least one sensor may comprise at least one vision-based sensor configured to generate vision-based data indicative of a fill-level of the implement. The computing system may be configured to determine the current vertical height of the dump pile based at least in part on a fill-level of at least one previous load of worksite materials.

[0015] The at least one sensor may comprise at least one payload sensor configured to generate data indicative of a weight of the load of worksite materials contained by the implement. The computing system may be configured to determine the current vertical height of the dump pile based at least in part on a weight of at least one previous load of worksite materials.

[0016] The input associated with initiating the automated dumping operation may be received in response to the weight of the load of worksite materials being equal to or greater than a weight threshold.

[0017] The computing system may be further configured to:

determine a predicted height of the dump pile associated with adding the load of worksite materials to the dump pile based at least in part on the weight of the load of worksite materials and the current vertical height of the dump pile; and

compare the predicted height of the dump pile to a height threshold for the dump pile.

[0018] The computing system may be configured to control an operation of the work vehicle to move the implement to the dumping height if the predicted height of the dump pile is less than the height threshold.

[0019] The computing system may be configured to determine the dumping height based at least in part on the current vertical height of the dump pile and a predetermined vertical offset.

[0020] In another aspect, the present subject matter is directed to a method for automatically controlling an operation of a work vehicle during the performance of an earthmoving operation, where the work vehicle has a lift assembly including a boom and an implement coupled to the boom, with the implement being pivotable relative to the boom between a load-carrying position and a load-dumping position. The method includes receiving, with one or more computing devices, an input associated with initiating an automated dumping operation to allow a load of worksite materials contained by the implement to be released onto a dump pile located at a dump location within a worksite. Further, the method includes determining, with the one or more computing devices, a current vertical height of the dump pile based at least in part on data indicative of a vertical height of the dump pile from at least one sensor, and determining, with the one or more computing devices, a dumping height of the implement for performing the dumping operation based at least in part on the current vertical height of the dump pile. Moreover, the method includes controlling, with the one or more computing devices, an operation of the lift assembly to move the implement to the dumping height in response to receiving the input associated with initiating the automated dumping operation. Additionally, the method includes controlling, with the one or more computing devices, an operation of the lift assembly to pivot the implement relative to the boom from the load-carrying position to the load-dumping position to release the load of worksite materials onto the dump pile from the dumping height.

[0021] The at least one sensor may comprise at least one vision-based sensor configured to generate vision-based data indicative of the vertical height of the dump pile. Determining the current vertical height of the dump pile may comprise determining the current vertical height of the dump pile based at least in part on the vision-based data.

[0022] The at least one vision-based sensor may be further configured to generate vision-based data indicative of a fill-level of the implement. Receiving the input associated with initiating the automated dumping operation may comprise receiving the input associated with initiating the automated dumping operation in response to the fill-level of the implement being equal to or greater than a fill-level threshold.

[0023] The method may further comprise:

> determining, with the one or more computing devices, a predicted height of the dump pile associated with adding the load of worksite materials to the dump pile based at least in part on the fill-level of the implement and the current vertical height of the dump pile; and
>
> comparing, with the one or more computing devices, the predicted height of the dump pile to a height threshold for the dump pile.

[0024] Controlling the operation of the lift assembly to move the implement to the dumping height may comprise controlling the operation of the lift assembly to move the implement to the dumping height if the predicted height of the dump pile is less than the height threshold.

[0025] The at least one sensor may comprise at least one vision-based sensor configured to generate vision-based data indicative of a fill-level of the implement. Determining the current vertical height of the dump pile may comprise determining the current vertical height of the dump pile based at least in part on a fill-level of at least one previous load of worksite materials.

[0026] The at least one sensor may comprise at least one payload sensor configured to generate data indicative of a weight of the load of worksite materials contained by the implement. Determining the current vertical height of the dump pile may comprise determining the current vertical height of the dump pile based at least in part on a weight of at least one previous load of worksite materials.

[0027] Receiving the input associated with initiating the automated dumping operation may comprise receiving the input associated with initiating the automated dumping operation in response to the weight of the load of worksite materials being equal to or greater than a weight threshold.

[0028] The method may further comprise:

> determining, with the one or more computing devices, a predicted height of the dump pile associated with adding the load of worksite materials to the dump pile based at least in part on the weight of the load of worksite materials and the current vertical height of the dump pile; and
>
> comparing, with the one or more computing devices, the predicted height of the dump pile to a height threshold for the dump pile,

[0029] Controlling an operation of the work vehicle to move the implement to the dumping height may comprise controlling an operation of the work vehicle to move the implement to the dumping height if the predicted height of the dump pile is less than the height threshold.

[0030] These and other features, aspects and advantages of the present invention will become better understood with reference to the following description and appended claims. The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] A full and enabling disclosure of the present invention, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the specification, which makes reference to the appended figures, in which:

> **FIG. 1** illustrates a side view of one embodiment of a work vehicle in accordance with aspects of the present subject matter;
>
> **FIG. 2** illustrates a schematic view of a system for automatically controlling an operation of a work vehicle during the performance of an earthmoving operation in accordance with aspects of the present subject matter;
>
> **FIGS. 3A-3C** illustrate various side views of an implement of a work vehicle during the performance of subsequent earthmoving operations in accordance with aspects of the present subject matter; and
>
> **FIG. 4** illustrates a flow diagram of one embodiment of a method for automatically controlling an operation of a work vehicle during the performance of an earthmoving operation in accordance with aspects of the present subject matter.

[0032] Repeat use of reference characters in the present specification and drawings is intended to represent the same or analogous features or elements of the present technology.

DETAILED DESCRIPTION OF THE INVENTION

[0033] Reference now will be made in detail to embodiments of the invention, one or more examples of which are illustrated in the drawings. Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit of the invention. For instance, features illustrated or described as part of one embodiment can be used with another embodiment to yield a still further embodiment. Thus, it is intended that the present invention covers such modifications and variations as come within the scope of the appended claims and their equivalents.

[0034] In general, the present subject matter is directed to systems and methods for automatically controlling an operation of a work vehicle during the performance of an earthmoving operation, particularly a dumping operation. In several embodiments, a control system of a work vehicle, such as an excavator or backhoe, may be configured to automatically control the operation of a lift assembly of the work vehicle, where the lift assembly includes a boom and an implement coupled to the boom, and where the implement is pivotable relative to the boom between a load-carrying position and a load-dumping position. Particularly, the control system may be configured to estimate or determine a current vertical height of a dump pile at a dump location within a worksite onto which a load of worksite materials contained by the implement may be dumped when the implement is pivoted from the load-carrying position to the load-dumping position. The control system may be configured to estimate or determine the current vertical height of the dump pile based at least in part on data that is directly or indirectly indicative of the current vertical height of the dump pile. For example, the control system may be configured to estimate or determine the current vertical height of the dump pile based at least in part on vision-based directly indicative of the current vertical height of the dump pile, vision-based data indicative of a fill-level of the implement, which is indirectly indicative of the current vertical height of the dump pile, and/or based at least in part on weight data indicative of a weight of at least one previous the load of materials contained within the implement, which is also indirectly indicative of the current vertical height of the dump pile. Once the current vertical height of the dump pile is determined, the control system may determine a dumping height of the implement for performing the dumping operation based at least in part on the current vertical height of the dump pile. In response to receiving an input associated with initiating a dumping operation, the control system may control the operation of the lift assembly to move the implement to the dumping height and to pivot the implement relative to the boom from the load-carrying position to the load-dumping position to release the load of worksite materials onto the dump pile from the dumping height. By automatically controlling the operation of the work vehicle during a dumping operation as disclosed herein, at least a closer estimation of the current vertical height of the dump pile is determined, which allows for a more efficient dumping operation.

[0035] Referring now to drawings, FIG. 1 illustrates a side view of one embodiment of a work vehicle 10 in accordance with aspects of the present subject matter. As shown, the work vehicle 10 is configured as an excavator. However, in other embodiments, the work vehicle 10 may be configured as any other suitable work vehicle, such as a loaders, shovels, backhoe, bull-dozers, and/or the like, that includes a lift assembly for performing an earthmoving operation, such as the dumping operation disclosed herein.

[0036] As shown in FIG. 1, the work vehicle 10 includes a frame or chassis 14 coupled to and supported by a pair of tracks 16 for movement across a worksite surface 17 of a worksite. However, in other embodiments, the chassis 14 may be supported in any other way, for example by wheels, a combination of wheels and tracks, or a fixed platform. In some embodiments, an operator's cab 18 may be supported by a portion of the chassis 14 and may house a user interface 60 (FIG. 2) having various input devices for permitting an operator to control the operation of one or more components of the work vehicle 10. However, it should be appreciated that, in some embodiments, one or more components of the user interface 60 may be positioned remotely from the work vehicle 10. Additionally, the work vehicle 10 includes a lift assembly 19 including an implement 20 and a boom 22, the implement 20 being pivotable relative to the boom 22 between a load-carrying position and a load-dumping position, as will be described in greater detail below, for performing earth moving operations within a worksite. The chassis 14 may, in some embodiments, be configured such that the operator's cab 18 and/or the lift assembly 19 is rotatable about a chassis axis 14A.

[0037] More particularly, the boom 22 includes a boom arm 24 and a dipper arm 26. The boom arm 24 extends between a first end 24A and a second end 24B. Similarly, the dipper arm 26 extends between first end 26A and a second end 26B. The first end 24A of the boom arm 24 is pivotably coupled to the chassis 14 about a first pivot axis 28, and the second end 24B of the boom arm 24 is pivotably coupled to the first end 26A of the dipper arm 26 about a second pivot axis 30. Further, the implement 20 is pivotably coupled to the second end 26B of the dipper arm 26 about a third pivot axis 32. The implement 20, in one embodiment, is configured as a bucket having a cavity 20A and a plurality of teeth 20B, where the teeth 20B help to break up worksite materials at dig site DG for collection within the cavity 20A. However, in other embodiments, the implement 20 may be configured as any other suitable ground engaging tool, such as a claw, and/or the like.

[0038] The lift assembly 19 further includes a plurality of actuators for articulating the implement 20, the boom arm 24, and dipper arm 26. For instance, a first actuator 34A is coupled between the boom arm 24 and the chassis 14 for pivoting the boom arm 24 relative to the chassis 14. Similarly, a second actuator 34B is coupled between the boom arm 24 and the dipper arm 26 for pivoting the dipper arm 26 relative to the boom arm 24. Further, a third actuator 34C is coupled between the dipper arm 26 and the implement 20 (hereafter referred to as "bucket 20" for the sake of simplicity and without intent to limit) for pivoting the bucket 20 relative to the dipper arm 26. In one embodiment, the actuators 34A, 34B, 34C are configured as hydraulic cylinders. However, it should be appreciated that the actuators 34A, 34B, 34C may be configured as any other suitable actuators or combination of actuators. By selectively pivoting the components 24, 24, 26 of the lift assembly 19, the bucket 20 may perform various earthmoving operations within a worksite. In particular, the bucket 20 may be actuatable over any portion of horizontal stroke length HR1, where the stroke length HR1 generally extends from adjacent the tracks 16 to where the bucket 20 is fully extended away from the cab 18, and over any portion of a vertical height range VR1.

[0039] Still referring to FIG. 1, the lift assembly 19 may also include a plurality of sensors for monitoring various operating parameters of the work vehicle 10 and or worksite. For instance, the work vehicle 10 may include one of more vision-based sensors 36 configured to generate data indicative of the bucket 20 and/or the worksite. More particularly, the vision-based sensor(s) 36 may be positioned such that a field of view 36A of each vision-based sensor 36 is directable towards the bucket 20 and/or the worksite. For example, the vision-based sensor(s) 36 may be supported on the operator's cab 18, the bucket 20, and/or the arm(s) 24, 26. In some embodiments, the vision-based sensor(s) 36 may be movable relative to the respective portion of the work vehicle 10 on which it is supported (e.g., the cab 18, the bucket 20, and/or arms 24, 26). More specifically, in embodiments where the vision-based sensor(s) 36 is configured to generate data indicative of the bucket 20, the vision-based sensor(s) 36 may generate data indicative of a volume of the cavity 20A of the bucket 20, the filled volume or fill-level of the cavity 20A of the bucket 20, and/or wear on one or more of the teeth 20B of the bucket 20. Similarly, in embodiments where the vision-based sensor(s) 36 is configured to generate data indicative of the worksite, the vision-based sensor(s) 36 may generate data indicative of the contour of the worksite, such as a height of the dump pile DP and/or depth of the dig site DG. The vision-based sensor(s) 36 may be configured as any suitable device or combination of devices for generating such data, such as a camera(s), a radio detection and ranging (RADAR) sensor(s), and/or a light detection and ranging (LIDAR) device. Such data may be used to control the operation of the bucket 20 and/or monitor the performance of the bucket 20 during an earth moving operation, as will be described in greater detail below.

[0040] Similarly, as shown in **FIG. 1,** one or more position sensors 38 may be positioned on one or more components of the work vehicle 10 for determining and/or monitoring the position of the bucket 20. For instance, the position sensor(s) 38 may be configured to generate data indicative of rotation of the components of the lift assembly 19 about the pivot axes 28, 30, 32, extension of the actuator(s) 34A, 34B, 34C, and/or the like. For example, the position sensor(s) 38 may include accelerometer(s), gyroscope(s), inertial measurement unit(s) (IMU(s)), rotational sensor(s), proximity sensor(s), displacement sensor(s), a combination of such sensors, and/or the like. Additionally, one or more payload sensors 40 may be positioned on one or more components of the work vehicle 10 for determining and/or monitoring the weight of a load of worksite materials contained within the bucket 20. For instance, the payload sensor(s) 40 may be configured to monitor the forces acting on the components of the lift assembly, such as the pressure within the cylinders 34A, 34B, 34C, which may be indicative of the weight of the load of worksite materials contained within the bucket 20. For example, the payload sensor(s) 40 may include pressure sensors, torque sensors, a combination of such sensors, and/or the like.

[0041] As will be described below in greater detail, the actuators 34A, 34B, 34C of the work vehicle 10 may be controlled by a controller of the disclosed system to automatically perform one or more tasks of an earthmoving operation for a worksite, such as a dumping operation to release a load of worksite materials contained by the bucket 20 (e.g., a load of worksite materials captured from the dig site DG) onto a dump pile DP at a dump location within the worksite spaced apart from the dig site DG in a horizontal direction across the worksite. Particularly, the actuators 34A, 34B, 34C of the work vehicle 10 may be controlled by the controller of the disclosed system based at least in part on the current vertical height of the dump pile DP determined based at least in part on the data from the vision based sensor(s) 36 and/or the payload sensor(s) 40.

[0042] It should be appreciated that the configuration of the work vehicle 10 described above and shown in **FIG. 1** is provided only to place the present subject matter in an exemplary field of use. Thus, it should be appreciated that the present subject matter may be readily adaptable to any manner of work vehicle configuration. For example, in an alternative embodiment, the work vehicle 10 may further include any other tools, implements, and/or components appropriate for use with a work vehicle 10.

[0043] Referring now to **FIG. 2,** a schematic view of one embodiment of a system 200 for automatically controlling an operation of a work vehicle during the performance of an earthmoving operation is illustrated in accordance with aspects of the present subject matter. In general, the system 200 will be described herein with reference to the work vehicle 10 described above with reference to FIG. 1. However, it should be appreciated by those of ordinary skill in the art that the disclosed system 200 may generally be utilized with work vehicles having any suitable vehicle configuration. Additionally, it should be appreciated that, for purposes of illustration, communicative links or electrical couplings of the system 200 shown in FIG. 2 are indicated by dashed lines.

[0044] In several embodiments, the system 200 may include a computing system 202 and various other components, features, systems and/or sub-systems configured to be communicatively coupled to the computing system 202. In general, the computing system 202 may be configured to perform various computer-related functions or tasks, including, for example, receiving data from one or more components, features, systems and/or sub-systems of the work vehicle 10, storing and/or processing data received or generated by the computing system 202, and/or controlling the operation of one or more components, features, systems and/or sub-systems of the work vehicle 10.

[0045] In general, the computing system 202 may correspond to any suitable processor-based device(s), such as a computing device or any combination of computing devices. Thus, as shown in **FIG. 2,** the computing system 202 may generally include one or more processor(s) 204 and associated memory devices 206 configured to perform a variety of computer-implemented functions (e.g., performing the methods, steps, and the like disclosed herein). As used herein, the term "processor" refers not only to integrated circuits referred to in the art as being included in a computer, but also refers to a controller, a microcontroller, a microcomputer, a programmable logic controller (PLC), an application specific integrated circuit, and other programmable circuits. Additionally, the memory device 206 may generally comprise memory element(s) including, but not limited to, computer readable medium (e.g., random access memory (RAM)), computer readable non-volatile medium (e.g., a flash memory), a floppy disk, a compact disc-read only memory (CD-ROM), a magneto-optical disk (MOD), a digital versatile disc (DVD) and/or other suitable memory elements. Such memory device 206 may generally be configured to store information accessible to the processor(s) 204, including data that can be retrieved, manipulated, created and/or stored by the processor(s) 204 and instructions that can be executed by the processor(s) 204.

[0046] As further shown in **FIG. 2,** the computing system 202 is configured to be communicatively coupled to various components of the work vehicle 10, including machine actuator(s) (e.g., actuator(s) 34A, 34B, 34C), vision-based sensor(s) 36, position sensor(s) 38, payload sensor(s) 40, and/or a user interface (e.g., user interface 60) having one or more input devices. As such, the computing system 202 may be configured to receive inputs from the different input devices 36, 38, 40, 60 and to control the operation of the actuator(s) 34 and/or the user interface 60 based at least in part on the inputs from the input device(s) 36, 38, 40, 60. The user interface 60 described herein may include, without limitation, any combination of input and/or output devices that allow an operator to provide operator inputs to the computing system 202 and/or that allow the computing system 202 to provide feedback to the operator, such as a keyboard, keypad, pointing device, buttons, knobs, touch sensitive screen, mobile device, audio input device, audio output device, and/or the like.

[0047] Additionally, in some embodiments, the computing system 202 may be configured to include one or more communications modules or interfaces 208 for the computing system 202 to communicate with any of the various system components described herein. For instance, one or more communicative links or interfaces (e.g., one or more data buses) may be provided between the communications interface 208 and the vision-based sensor(s) 36 to allow the computing system 202 to receive data directly indicative of a height of the dump pile DP at a dump site within the worksite and/or data indicative of a fill-level of the implement (e.g., bucket 20) from the vision-based sensor(s) 36. Similarly, one or more communicative links or interfaces (e.g., one or more data buses) may be provided between the communications interface 208 and the position sensor(s) 38 to allow the computing system 202 to receive data indicative of a position of the implement (e.g., bucket 20) relative to the chassis 14 and/or worksite from the position sensor(s) 38. Moreover, one or more communicative links or interfaces (e.g., one or more data buses) may be provided between the communications interface 208 and the payload sensor(s) 40 to allow the computing system 202 to receive data indicative of the weight of a load of worksite materials contained by the implement (e.g., bucket 20) from the payload sensor(s) 40. Additionally, one or more communicative links or interfaces (e.g., one or more data buses) may be provided between the communications interface 208 and the user interface 60 to allow the computing system 202 to receive an input associated with initiating an earthmoving operation (e.g., a dumping operation to allow the load of worksite materials contained by the implement to be released onto a dump pile DP) with the implement (e.g., bucket 20), a location of the dump pile DP, one or more thresholds, and/or the like from the user interface 60.

[0048] In accordance with aspects of the present subject matter, in several embodiments, when an input associated with initiating an earthmoving operation (e.g., a dumping operation) is received, the computing system 202 may be configured to determine a current vertical height of the dump pile DP. More particularly, the dump pile DP has a generally conical shape such that, after each dumping operation, a vertical height and a radius of the dump pile DP grow. However, due to the conical shape of the dump pile DP and variations in the fill-level of the bucket across subsequent dumping operations, the growth of at least the vertical height is not linear (e.g., by a set increment). As such, the computing system 202 is configured to determine a current vertical height of the dump pile DP, prior to controlling the implement to perform the dumping operation, to ensure the most efficient movement of the implement. It should be appreciated that the computing system 202 may be configured to determine the current vertical height of the dump pile DP preemptively, after a first dumping operation and before receipt of an input associated with initiating a second dumping operation and stored within the memory 206 of the computing system 202, or in response to receiving an input associated with initiating a dumping operation.

[0049] The computing system 202 may determine the current vertical height of the dump pile DP based at least in part on data from the sensor(s) 36, 40. For instance, in one embodiment, as indicated above, vision-based data from the vision-based sensor(s) 36 may be directly indicative of the current vertical height of the dump pile DP. As such, the computing system 202 may be configured to determine the current height of the dump pile DP based on a direct correlation between the data from the vision-based sensor(s) 36 and the height of the dump pile DP. Alternatively, or additionally, in some embodiments, vision-based data from the vision-based sensor(s) 36 may be indicative of a fill-level of the bucket 20, which is indirectly indicative of the vertical height of the dump pile DP. Particularly, the current vertical height of the dump pile DP may be determined at least in part on a fill-level of at least one previous load of worksite materials. For instance, one or more known algorithms or tables may be stored in the memory 206 of the computing system 202 that correlate the fill-level of the bucket 20 and the dimensions of the bucket 20 to a volume of the load of worksite materials within the bucket 20. It should be appreciated that the dimensions of the bucket 20 may similarly be determined based at least in part on data from the vision-based sensor(s) 36 and/or may be provided in any other suitable manner. The cumulative volume of the previous load(s) may indicate the current vertical height of the dump pile DP. For example, one or more known algorithms or tables may be stored in the memory 206 of the computing system 202 that correlate the cumulative volume of the at least one previous load of worksite materials to a current vertical height of the dump pile DP. However, it should be appreciated that any other suitable relationships between the fill-level of at least one previous load of worksite materials and the current vertical height may instead or additionally be used.

[0050] Similarly, in some embodiments, as indicated above, data from the payload sensor(s) 40 may be indicative of a weight of the load of worksite materials contained within the bucket 20, which is indirectly indicative of the vertical height of the dump pile DP. Particularly, the current vertical height of the dump pile DP may be determined at least in part on a weight of the at least one previous load of worksite materials. For instance, the memory 206 of the computing system 202 may include any suitable algorithms or tables for the given configuration of the lift assembly 19 correlating the data received from the position sensor(s) 38 indicative of the positions of the components of the lift assembly 19 and the data from the payload sensor(s) 40 indicative of the loads acting on the lift assembly (e.g., the pressure within the actuator(s) 34) to a weight of the load of worksite materials. One or more known algorithms or tables may be stored in the memory 206 of the computing system 202 that then correlate the cumulative weight of the previous load(s) of worksite materials to a current vertical height of the dump pile DP. However, it should be appreciated that any other suitable relationships between the weight of the previous load(s) of worksite materials and the current vertical height may instead or additionally be used.

[0051] Once the current vertical height of the dump pile DP is determined, the computing system 202 may be configured to determine a dumping height for the implement for performing the dumping operation. The dumping height is generally defined between the pivot axis 32 (about which the implement pivots between the load-carrying and load-dumping positions) and the worksite surface 17. The dumping height DH may be equivalent to a sum of the current vertical height of the dump pile and a vertical offset. The vertical offset is selected such that the bucket 20 is located at the same distance vertically above the dump pile DP for each dumping operation and such that the bucket 20 does not contact the dump pile DP when being moved during the dumping operation. For instance, in one embodiment, the vertical offset is equal to or slightly larger than a largest radius of the bucket 20 when the bucket 20 pivots about the pivot axis 32 (e.g., the distance between the tips of the teeth 20B and the pivot axis 32). However, in other embodiments, the vertical offset may be selected in any other suitable way. In some instances, the vertical offset may be predetermined and stored within the memory 206 of the computing system 202.

[0052] Thereafter, the computing system 202 may further be configured to determine a suitable travel path for moving the bucket 20 during the dumping operation based at least in part on the dumping height. For instance, after the dig operation at the dig site DG is complete and the input associated with initiating the dumping operation is received, the bucket 20 may be disposed at or adjacent the dig site DG. The computing system 202 may thus, be configured to create a travel path for the bucket 20 from the starting position of the bucket 20 at or adjacent the dig site DG to an ending point at the determined dumping height, adjacent the dump pile DP, such that the bucket 20 may be moved across the horizontal distance and the vertical distance between the starting position to the ending point. Preferably, the ending point is selected such that, when the bucket 20 is at or near the ending point, the bucket 20 is pivoted about the pivot axis 32 from the load-carrying position to the load-dumping position, and the load of worksite materials is released onto the dump pile DP (e.g., onto a center of the dump pile DP). Further, the path is generated such that, as the bucket 20 is moved across the vertical distance between the starting position and the ending point, the bucket 20 does not intercept the dump pile DP. It should be appreciated that the travel path may have any suitable shape such as, for example, linear, curved, and/or the like. It should further be appreciated that the general shape of the travel path may be predetermined or selected in any suitable manner.

[0053] In some embodiments, the travel path may further include a dump-initiation position at which the bucket 20 begins to move from the load-carrying position to the load-dumping position. In general, the closer the bucket 20 is pivoted toward the load-dumping position before the bucket 20 reaches the ending point, the quicker the dumping operation is completed. Thus, based on the detected fill-level of the bucket 20 (e.g., based on vision-based or load-based data), the dump-initiation position may be selected such that the time to perform the dumping operation to unload the load onto the dump pile DP may be reduced. In some embodiments, the dump-initiation position is the same as the ending point of the travel path. For example, if the bucket 20 is determined to be full or over-full (heaped), the bucket 20 may begin releasing the load with very little rotation from the load-carrying position to the load-dumping position. As such, when the bucket 20 is very full, the dump-initiation position must be at or very close to the ending point such that none or very little of the load is released from the bucket 20 before reaching the dump pile DP. However, if the bucket 20 is less full, the bucket 20 has to be rotated further from the load-carrying position to the load-dumping position to begin releasing the load from the bucket 20. As such, the less full the bucket 20 is, the further the dump-initiation position may be from the ending point. In some embodiments, the dump-initiation position is further selected based on the material type of the load. For instance, looser materials may begin unloading sooner than more compact materials. In one embodiment, one or more known algorithms or tables may be stored in the memory 206 of the computing system 202 that correlate the fill-level and/or material type of the current load of worksite materials to dump-initiation position or distance relative to the ending point.

[0054] After creating the travel path, the computing system 202 may control the operation of the lift assembly 19 (e.g., the operation of the actuator(s) 34A, 34B, 34C) to move the bucket 20 along the travel path to the ending point. In some embodiments, the computing system 202 may be optionally configured to determine whether the current load of work materials may be added to the dump pile DP before the bucket 20 is moved to the ending point. For instance, in some embodiments, the vertical height of the dump pile DP cannot exceed a given height threshold, for example, to be within limitations of the work vehicle (or other work vehicles within the worksite) and/or to reduce the risk of cave-ins into a nearby dig site DG. As such, the computing system 202 may be configured to determine a predicted height of the dump pile associated with adding the load of worksite materials to the dump pile. For example, based at least in part on vision-based data from the vision-based sensor(s) 36 indicative of a fill-level of the bucket 20, the predicted height of the dump pile may be determined by finding the vertical height associated with the sum of the volumes of worksite materials associated with the current fill-level of the bucket 20 and the previous load(s) of worksite materials. Alternatively, or additionally, based at least in part on data from the payload sensor(s) 40 indicative of the weight of the load of worksite materials contained within the bucket 20, the predicted height of the dump pile may be determined by finding the vertical height associated with the sum of the weights of the current load of worksite materials of the bucket 20 and the previous load(s) of worksite materials. The computing system 202 may then compare the predicted height of the dump pile DP to a height threshold. If the predicted height of the dump pile DP is less than the height threshold, the bucket 20 may be moved to the ending point. Otherwise, a new dump pile location is selected and/or an error is indicated to the operator via the user interface 60.

[0055] Further, in some embodiments, the computing system 202 may be configured to determine if lifting the current load of worksite materials to the ending point would create a tipping risk for the work vehicle 10. In general, if the weight of the current load of worksite materials is within the lifting capacity of the work vehicle 10, but closer to an upper end of such lifting capacity, lifting to an ending point that is high may be more likely to cause the work vehicle 10 to tip. As such, the computing system 202 may be configured to compare the dumping height for performing the dumping operation (e.g., the height of the ending point) to a tip height limit. If the dumping height (e.g., the height of the ending point) is less than the tip height limit, the bucket 20 may be moved to the ending point. Otherwise, a new dump pile location is selected and/or an error is indicated to the operator via the user interface 60. It should be appreciated that the tip height limit may be selected based at least in part on the current weight of the load of worksite materials. For instance, one or more known algorithms or tables may be stored in the memory 206 of the computing system 202 that correlate the weight of the current load of worksite materials to a tip height limit for preventing tipping of the machine 10. However, the tip height limit may otherwise be selected.

[0056] Once the bucket 20 is at the ending point, the computing system 202 may further automatically control the operation of the lift assembly 19 (e.g., the operation of the actuator(s) 34C) to pivot the bucket 20 about the pivot axis 32 from the load-carrying position to the load-dumping position to allow the load of worksite materials contained within the bucket 20 to be released from the bucket 20 onto the dump pile DP. In some embodiments, the computing system 202 may additionally be configured to automatically control the operation of the lift assembly 19 (e.g., the operation of the actuator(s) 34A, 34B, 34C) to return the bucket 20 to a dig-start position adjacent the dig site DG for a subsequent dig operation.

[0057] It should be appreciated that the input associated with initiating the dumping operation may be received in any suitable way. For instance, in some embodiments, the input associated with initiating the dumping operation may be received from the operator via the user interface 60, may be received based on a position of the implement 20, and/or may be received in response to sensor data from the vision-based sensor(s) 36 and/or the payload sensor(s) 40. For example, in one embodiment, the operator may be configured to manipulate the user interface 60 (e.g., press a button, flip a switch, etc.) to provide the input associated with initiating the dumping operation to the computing system 202. In some embodiments, the computing system 202 may be configured to compare a current height of the bucket 20 relative to the worksite surface 17 (e.g., based on the data from the position sensor(s) 38) to a dump-initiation height threshold. When computing system 202 receives data from the position sensor(s) 38 indicative of the bucket 20 being at or above the dump-initiation height threshold, the computing system 202 determines that a dumping operation should be initiated. Similarly, in one embodiment, the computing system 202 may be configured to determine the current fill-level of the bucket 20 based at least in part on the vision-based data indicative of the fill-level of the bucket 20 received from the vision-based sensor(s) 36. The computing system 202 may then be configured to compare the current fill-level of the bucket 20 to one or more fill-level thresholds. If the current fill-level of the bucket 20 exceeds one or more of the fill-level thresholds, then the computing system 202 may be configured to determine that a dumping operation should be initiated. Alternatively, or additionally, in some embodiments, the computing system 202 may be configured to determine the current weight of the load of worksite materials contained by the bucket 20 based at least in part on the data indicative of the weight of the load of worksite materials received from the payload sensor(s) 40 and the data indicative of the position of the lift assembly 19 received from the position sensor(s) 38, in the same manner as described above. The computing system 202 may then be configured to compare the weight of the load of worksite materials currently contained by the bucket 20 to one or more weight thresholds. If the current weight of the load of worksite materials contained by the bucket 20 exceeds one or more of the weight thresholds, then the computing system 202 may be configured to determine that a dumping operation should be initiated.

[0058] Referring now to FIGS. 3A-3C, side views of an example implementation of the automatic control of the work vehicle during the performance of subsequent earthmoving operations are illustrated in accordance with aspects of the present subject matter. Generally, as shown in FIGS. 3A-3C, after a dig operation has been performed at a dig site DG, a load of worksite materials is contained within the bucket 20 while the bucket 20 is in the load-carrying position. In FIG. 3A, before a first dumping operation to release the load of worksite materials onto the dump pile DP, the dump pile DP (shown in solid lines) is determined to have a first vertical height V1 (e.g., based on the data from sensor(s) 36, 40 as described with reference to **FIG. 2)** and a first radius R1 (or width). It is determined (e.g., based on the data from sensor(s) 36, 40 as described with reference to **FIG. 2)** that the potential first dumping operation of FIG. 3A would increase the height of the dump pile DP from the first vertical height V1 to a predicted height (i.e., second vertical height V2), which is below the height threshold HT1, so the first dumping operation is determined to be allowed. As such, a first dumping height DH1 of the bucket 20 is determined that is equal to a sum of the first vertical height V1 of the initial dump pile DP and a vertical offset OH1. A first travel path P1 is then generated for the bucket 20 that extends from the starting point adjacent the dig site DG to an ending point adjacent the dump pile DP that is at the first dumping height DH1. Then, the bucket 20 is moved by the lifting assembly 19 (FIG. 1) along the first travel path P1 to the ending point. Once the bucket 20 is at the ending point, the bucket 20 is pivoted from the load-carrying position to the load-dumping position to unload the load of worksite materials onto the dump pile DP from above a center point C1 of the dump pile DP such that the dump pile DP grows (as shown in dashed lines). It should be appreciated that while the dumping operation is shown as releasing the load of work materials from above the center C1 of the dump pile DP, the load of work materials may be released from any other suitable location above or beside the dump pile DP such that the bucket 20 does not interfere with the dump pile DP when the dumping operation is performed.

[0059] After the first dumping operation in FIG. 3A, the dump pile DP (as shown in solid lines in FIG. 3B) is determined to have an updated current vertical height equal to a second vertical height V2 (e.g., based on the data from sensor(s) 36, 40 as described with reference to **FIG. 2),** which is taller than the first vertical height V1, and to have a second radius R2 (or width), which is larger than the first radius R1 (or width). When another dig operation is completed, it is determined (e.g., based on the data from sensor(s) 36, 40 as described with reference to **FIG. 2)** that the potential second dumping operation of **FIG. 3B** would increase the height of the dump pile DP from the current, second vertical height V2 to a predicted height (i.e., a third vertical height V3), which is still less than the height threshold HT1, so the second dumping operation is also determined to be allowed. As such, an updated dumping height (i.e., a second dumping height DH2) for the bucket 20 is determined that is equal to a sum of the second vertical height V2 of the dump pile DP and the vertical offset OH1. It should be appreciated that the second dumping height DH2 is taller than the first dumping height DH1 by more than the vertical offset OH1. A second travel path P2 is then generated for the bucket 20 that extends from the starting point adjacent the dig site DG to an ending point adjacent the dump pile DP that is at the second dumping height DH2. Then, the bucket 20 is moved by the lifting assembly 19 **(FIG. 1)** along the second travel path P2 to the ending point. Once the bucket 20 is at the ending point, the bucket 20 is pivoted from the load-carrying position to the load-dumping position to unload the load of worksite materials onto the dump pile DP from above a center point C1 of the dump pile DP such that the dump pile DP grows (as shown in dashed lines).

[0060] After the second dumping operation of **FIG. 3B,** the dump pile DP (as shown in solid lines in **FIG. 3C)** is determined to have an updated current height equal to a third vertical height V3 (e.g., based on the data from sensor(s) 36, 40 as described with reference to **FIG. 2),** which is taller than the first and second vertical heights

V1, V2, and to have a third radius R3 (or width), which is also larger than the first and second radii R1, R2 (or widths). An updated dumping height (i.e., a third dumping height DH3) for the bucket 20 is determined that is equal to a sum of the current, third vertical height V2 of the dump pile DP and the vertical offset OH1. A third travel path P3 is then generated for the bucket 20 that extends from the starting point adjacent the dig site DG to an ending point adjacent the dump pile DP that is at the third dumping height DH3. However, as it is determined (e.g., based on the data from sensor(s) 36, 40 as described with reference to **FIG. 2)** that the potential third dumping operation of **FIG. 3C** would increase the height of the dump pile DP from the current, third vertical height V3 to a predicted height (i.e., a fourth vertical height V4), which is greater than the height threshold HT1, the third dumping operation is determined to not be allowed. As such, an error message may be communicated to the operator via the user interface 60 **(FIG. 2)** and/or a new dump pile may be selected.

[0061] If a new dump pile is selected, then a similar process may be performed for the new dump pile. For instance, the current height of the new dump pile may be determined, a dumping height of the bucket 20 for the new dump pile may be determined, a travel path for the bucket 20 to an ending point at the new dump pile at the determined dumping height may be determined, the bucket 20 may be moved along the travel path to the ending point for the new dump pile, and then the bucket 20 may be pivoted to the load-dumping position such that the load of worksite materials may be released onto the new dump pile.

[0062] It should be appreciated that while the dumping operation is shown as releasing the load of work materials from above the center C1 of the dump pile DP, the load of work materials may be released from any other suitable location above or beside the dump pile DP such that the bucket 20 does not interfere with the dump pile DP when the dumping operation is performed. It should further be appreciated that the change between the first and second vertical heights V1, V2 and between the second and third vertical heights V2, V3 is not linear (e.g., by a set increment). Instead, in some embodiments, the increase in vertical height V between subsequent dumping operations decreases with each subsequent dumping operation. Additionally, it should be appreciated that while the illustrated examples show the dump pile DP being on the worksite surface, the dump pile DP may instead be located within a cavity of a dump truck, for example, without deviating from the scope of the present invention.

[0063] Referring now to **FIG. 4,** a flow diagram of one embodiment of a method 300 for automatically controlling an operation of a work vehicle during the performance of an earthmoving operation is illustrated in accordance with aspects of the present subject matter. In general, the method 300 will be described herein with reference to the work vehicle 10 described with reference to **FIG. 1,** and the computing system 200 described with reference to **FIGS. 2-3C.** However, it should be appreciated that the disclosed method 300 may be implemented with work vehicles having any other suitable configuration, and/or with systems having any other suitable system configuration for performing the method described. In addition, although **FIG. 4** depicts steps performed in a particular order for purposes of illustration and discussion, the methods discussed herein are not limited to any particular order or arrangement. One of ordinary skill in the art, using the disclosures provided herein, will appreciate that various steps of the method disclosed herein can be omitted, rearranged, combined, and/or adapted in various ways without deviating from the scope of the present disclosure.

[0064] As shown in FIG. 4, at (302), the method 300 may include receiving an input associated with initiating an automated dumping operation to allow a load of worksite materials contained by an implement of a lift assembly of a work vehicle to be released onto a dump pile at a dump location. For instance, as indicated above, the computing system 202 may receive an input associated with initiating an automated dumping operation to allow a load of worksite materials contained by the implement 20 of the lift assembly 19 of the work vehicle 10 to be released onto the dump pile DP at the dump location within a worksite.

[0065] Further, at (304), the method 300 may include determining a current vertical height of the dump pile based at least in part on the data from at least one sensor. For example, as described above, the computing system 202 may determine a current vertical height V of the dump pile DP based at least in part on data from at least one sensor 36, 40.

[0066] At (306), the method 300 may include determining a dumping height of the implement for performing the dumping operation based at least in part on the current vertical height of the dump pile. For instance, as described above, the computing system 202 may be determine a dumping height DH of the implement 20 for performing the dumping operation based at least in part on the current vertical height V of the dump pile DP.

[0067] Moreover, at (308), the method 300 may include controlling an operation of the lift assembly to move the implement to the dumping height in response to receiving the input associated with initiating the dumping operation. For example, as indicated above, the computing system may control the operation of the lift assembly 19, such as of one or more of the actuator(s) 34A, 34B, 34C of the lift assembly 19, to move the implement 20 to the dumping height DH in response to receiving the input associated with initiating the dumping operation.

[0068] Additionally, at (310), the method 300 may include controlling an operation of the lift assembly to pivot the implement relative to a boom of the lift assembly from a load-carrying position to a load-dumping position to release the load of worksite materials onto the dump pile from the dumping height. For instance, as discussed above, the computing system may further control an operation of the lift assembly 19 (e.g., of actuator(s) 34C) to pivot the implement 20 relative to the boom 22 from a load-carrying position to a load-dumping position to release the load of worksite materials onto the dump pile DP from the dumping height DH.

[0069] It is to be understood that the steps of the method 300 are performed by the computing system 200 upon loading and executing software code or instructions which are tangibly stored on a tangible computer readable medium, such as on a magnetic medium, e.g., a computer hard drive, an optical medium, e.g., an optical disk, solid-state memory, e.g., flash memory, or other storage media known in the art. Thus, any of the functionality performed by the computing system 200 described herein, such as the method 300, is implemented in software code or instructions which are tangibly stored on a tangible computer readable medium. The computing system 200 loads the software code or instructions via a direct interface with the computer readable medium or via a wired and/or wireless network. Upon loading and executing such software code or instructions by the computing system 200, the computing system 200 may perform any of the functionality of the computing system 200 described herein, including any steps of the method 300 described herein.

[0070] The term "software code" or "code" used herein refers to any instructions or set of instructions that influence the operation of a computer or computing system. They may exist in a computer-executable form, such as machine code, which is the set of instructions and data directly executed by a computer's central processing unit or by a computing system, a human-understandable form, such as source code, which may be compiled in order to be executed by a computer's central processing unit or by a computing system, or an intermediate form, such as object code, which is produced by a compiler. As used herein, the term "software code" or "code" also includes any human-understandable computer instructions or set of instructions, e.g., a script, that may be executed on the fly with the aid of an interpreter executed by a computer's central processing unit or by a computing system.

[0071] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they include structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

Claims

1. A system (200) for automatically controlling a work vehicle (10) during the performance of an earthmoving operation, the system (200) comprising a lift assembly (19) including a boom (24, 26) and an implement (20) coupled to the boom (24, 26), the implement (20) being pivotable relative to the boom (24, 26) between a load-carrying position and a load-dumping position, the system (200) being **characterized by**:

   at least one sensor (38, 40) supported relative to the lift assembly (19), the at least one sensor (38, 40) being configured to generate data indicative of a vertical height of a dump pile (DP) located at a dump location within a worksite; and
   a computing system (202) communicatively coupled to the work vehicle (10) and the at least one sensor (38, 40), the computing system (202) being configured to:

      receive an input associated with initiating an automated dumping operation to allow a load of worksite materials contained by the implement (20) to be released onto the dump pile (DP) at the dump location;
      determine a current vertical height (V1) of the dump pile (DP) based at least in part on the data from the at least one sensor (38, 40);
      determine a dumping height (DH1) of the implement (20) for performing the dumping operation based at least in part on the current vertical height (V1) of the dump pile (DP);
      control an operation of the lift assembly (19) to move the implement (20) to the dumping height (DH1) in response to receiving the input associated with initiating the dumping operation; and
      control an operation of the lift assembly (19) to pivot the implement (20) relative to the boom (24, 26) from the load-carrying position to the load-dumping position to release the load of worksite materials onto the dump pile (DP) from the dumping height (DH1).

2. The system (200) as in claim 1, **characterized by** the dump location being spaced apart from a current dig location (DG) of the work vehicle (10) in a horizontal direction across the worksite,

   characterized by the computing system (202) being further configured to determine a travel path (P1) for moving the implement (20) between a starting point disposed at or adjacent to the current dig location (DG) to an ending point disposed at or adjacent to the dump location, the ending point being positioned above the dump pile (DP) and at the dumping height (DH1), and

characterized by controlling the operation of the lift assembly (19) to move the implement (20) to the dumping height (DH1) by controlling the operation of the lift assembly (19) to move the implement (20) along the travel path (P1) from the starting point to the ending point.

3. The system (200) as in any preceding claim, **characterized by** the dumping operation being a first dumping operation, and
characterized by the computing system (202) being further configured to:

receive an input associated with initiating a subsequent automated dumping operation to allow a subsequent load of worksite materials contained by the implement (20) to be released onto the dump pile (DP) at the dump location, subsequent to the first dumping operation;
determine an updated current vertical height (V2) of the dump pile (DP) after the first dumping operation based at least in part on the data from the at least one sensor (38, 40);
determine an updated dumping height (DH2) of the implement (20) for performing the dumping operation based at least in part on the updated current vertical height (V2) of the dump pile (DP);
control an operation of the lift assembly (19) to move the implement (20) to the updated dumping height (DH2) in response to receiving the input associated with initiating the subsequent automated dumping operation; and
control an operation of the lift assembly (19) to pivot the implement (20) relative to the boom (24, 26) from the load-carrying position to the load-dumping position to release the subsequent load of worksite materials onto the dump pile (DP) from the updated dumping height (DH2).

4. The system (200) as in claim 3, wherein the dumping height (DH1) for the first dumping operation is disposed at a first vertical offset (OH1) above the dump pile (DP) and the updated dumping height (DH2) for the subsequent dumping operation is disposed at a second vertical offset (OH1) above the dump pile (DP), the first and second vertical offsets being equal.

5. The system as in any preceding claim, **characterized by** the at least one sensor (38, 40) being at least one vision-based sensor (38, 40) configured to generate vision-based data indicative of the vertical height (V1) of the dump pile (DP), and
characterized by the computing system (202) being configured to determine the current vertical height (V1) of the dump pile (DP) based at least in part on the vision-based data.

6. The system (200) as in claim 5, wherein the at least one vision-based sensor (38, 40) is further configured to generate vision-based data indicative of a fill-level of the implement (20), wherein the input associated with initiating the automated dumping operation is received in response to the fill-level of the implement (20) being equal to or greater than a fill-level threshold.

7. The system (200) as in claim 6, **characterized by** the computing system (202) being further configured to:

determine a predicted height (V2) of the dump pile (DP) associated with adding the load of worksite materials to the dump pile (DP) based at least in part on the fill-level of the implement (20) and the current vertical height (V1) of the dump pile (DP); and
compare the predicted height (V2) of the dump pile (DP) to a height threshold (HT1) for the dump pile (DP), and
characterized by the computing system (202) being configured to control the operation of the lift assembly (19) to move the implement (20) to the dumping height (DH1) if the predicted height (V2) of the dump pile (DP) is less than the height threshold (HT1).

8. The system (200) as in any preceding claim, **characterized by** the at least one sensor (38, 40) being at least one vision-based sensor (38, 40) configured to generate vision-based data indicative of a fill-level of the implement (20), and
characterized by the computing system (202) being configured to determine the current vertical height (V1) of the dump pile (DP) based at least in part on a fill-level of at least one previous load of worksite materials.

9. The system (200) as in any preceding claim, **characterized by** the at least one sensor (38, 40) being at least one payload sensor (38, 40) configured to generate data indicative of a weight of the load of worksite materials contained by the implement (20), wherein the computing system (202) is configured to determine the current vertical height (V1) of the dump pile (DP) based at least in part on a weight of at least one previous load of worksite materials.

10. The system (200) as in claim 9, **characterized by** the input associated with initiating the automated dumping operation being received in response to the weight of the load of worksite materials being equal to or greater than a weight threshold.

11. The system (200) as in claim 9 or 10, **characterized by** the computing system (202) being further configured to:

determine a predicted height (V2) of the dump pile (DP) associated with adding the load of worksite materials to the dump pile (DP) based at least in part on the weight of the load of worksite materials and the current vertical height (V1) of the dump pile (DP); and
compare the predicted height (V2) of the dump pile (DP) to a height threshold (HT1) for the dump pile (DP), and
characterized by the computing system (202) being configured to control an operation of the work vehicle (10) to move the implement (20) to the dumping height (DH1) if the predicted height (V2) of the dump pile (DP) is less than the height threshold (HT1).

12. The system (200) as in any preceding claim, **characterized by** the computing system (202) being configured to determine the dumping height (DH1) based at least in part on the current vertical height (V1) of the dump pile (DP) and a predetermined vertical offset (OH1).

13. A method (300) for automatically controlling an operation of a work vehicle (10) during the performance of an earthmoving operation, the work vehicle (10) having a lift assembly (19) including a boom (24, 26) and an implement (20) coupled to the boom (24, 26), the implement (20) being pivotable relative to the boom (24, 26) between a load-carrying position and a load-dumping position, the method (300) being **characterized by**:

receiving, with one or more computing devices, an input associated with initiating an automated dumping operation to allow a load of worksite materials contained by the implement (20) to be released onto a dump pile (DP) located at a dump location within a worksite;
determining, with the one or more computing devices, a current vertical height (V1) of the dump pile (DP) based at least in part on data indicative of a vertical height of the dump pile (DP) from at least one sensor (38, 40);
determining, with the one or more computing devices, a dumping height (DH1) of the implement (20) for performing the dumping operation based at least in part on the current vertical height (V1) of the dump pile (DP);
controlling, with the one or more computing devices, an operation of the lift assembly (19) to move the implement (20) to the dumping height (DH1) in response to receiving the input associated with initiating the automated dumping operation; and
controlling, with the one or more computing devices, an operation of the lift assembly (19) to pivot the implement (20) relative to the boom (24, 26) from the load-carrying position to the load-dumping position to release the load of worksite materials onto the dump pile (DP) from the dumping height (DH1).

14. The method (300) as in claim 13, **characterized by** the at least one sensor (38, 40) being at least one vision-based sensor (38, 40) configured to generate vision-based data indicative of the vertical height of the dump pile (DP), and
characterized by determining the current vertical height (V1) of the dump pile (DP) by determining the current vertical height (V1) of the dump pile (DP) based at least in part on the vision-based data.

15. The method (300) as in any preceding claim, wherein the at least one sensor (38, 40) comprises at least one payload sensor (38, 40) configured to generate data indicative of a weight of the load of worksite materials contained by the implement (20),
wherein determining the current vertical height (V1) of the dump pile (DP) comprises determining the current vertical height (V1) of the dump pile (DP) based at least in part on a weight of at least one previous load of worksite materials.

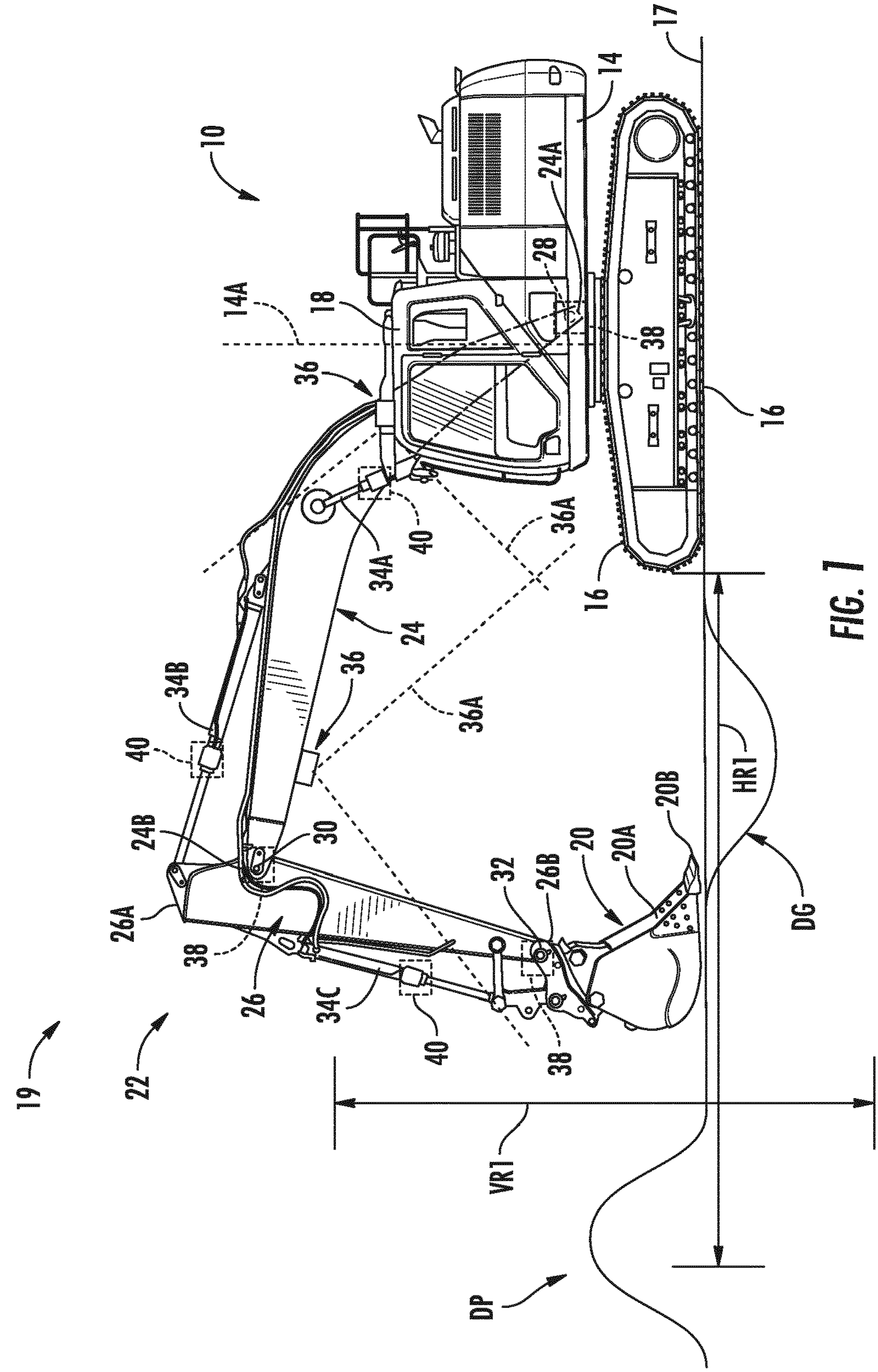
10
14
17
14A
18
28
24A
36
38
16
36A
40
34A
24
16
34B
40
36
36A
24B
30
20B
HR1
32
26B
20
20A
26A
38
26
34C
40
38
DG
19
22
VR1
DP

FIG. 1

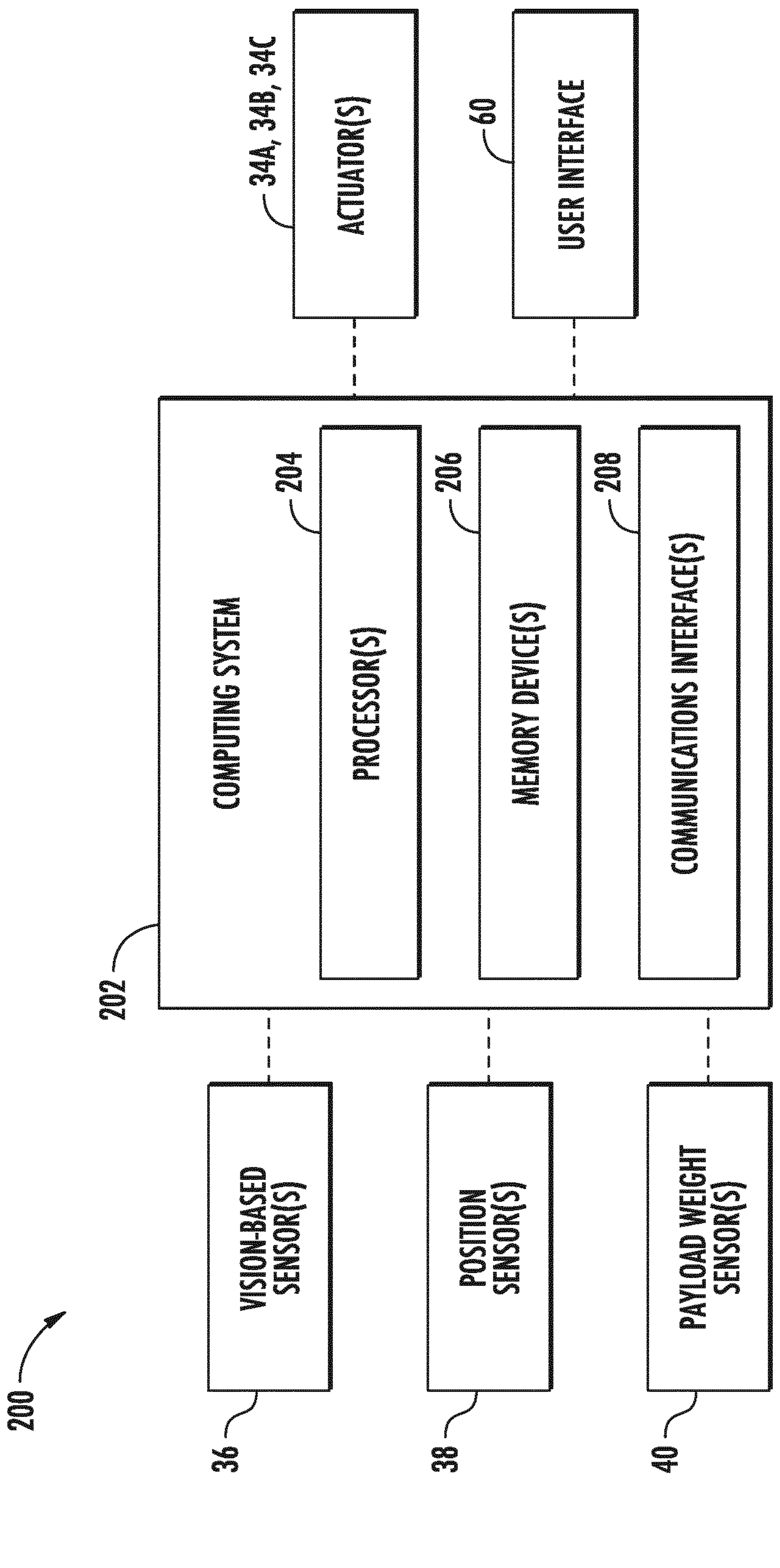
200
36
VISION-BASED SENSOR(S)
38
POSITION SENSOR(S)
40
PAYLOAD WEIGHT SENSOR(S)
202
COMPUTING SYSTEM
204
PROCESSOR(S)
206
MEMORY DEVICE(S)
208
COMMUNICATIONS INTERFACE(S)
34A, 34B, 34C
ACTUATOR(S)
60
USER INTERFACE

FIG. 2

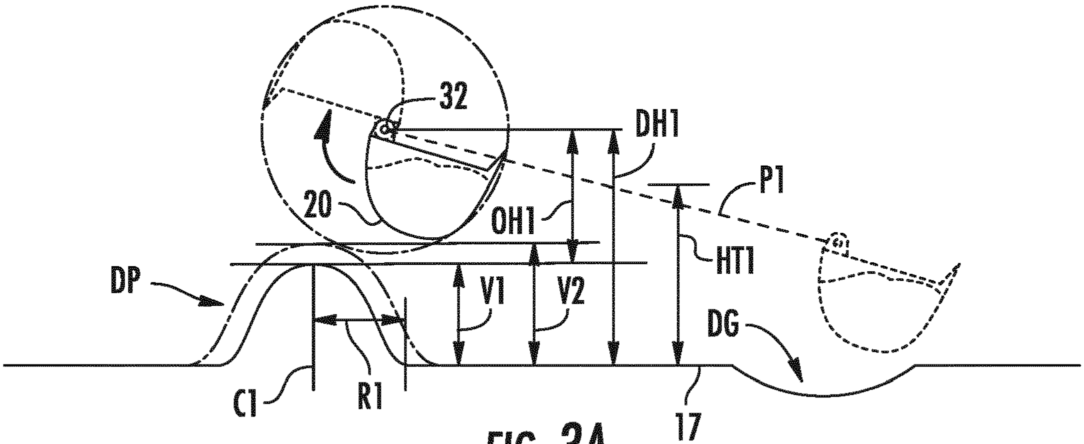

FIG. 3A

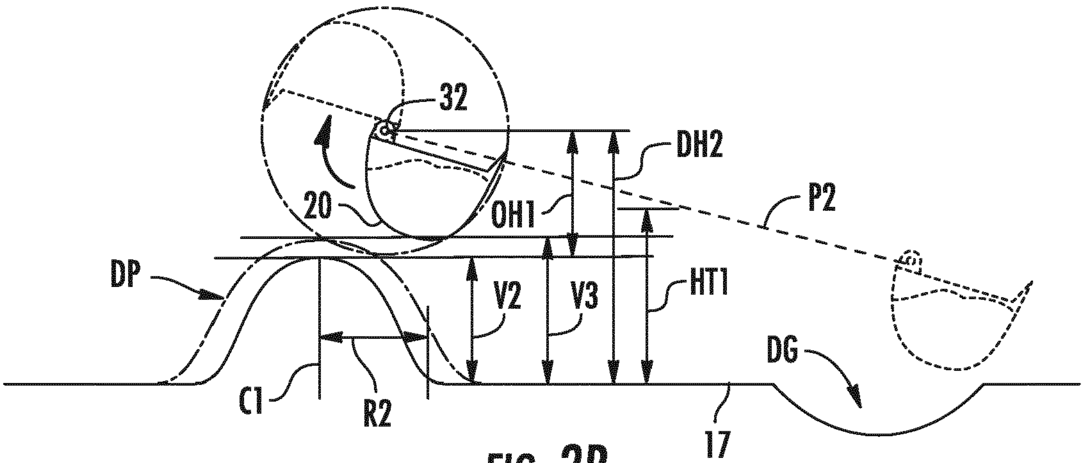

FIG. 3B

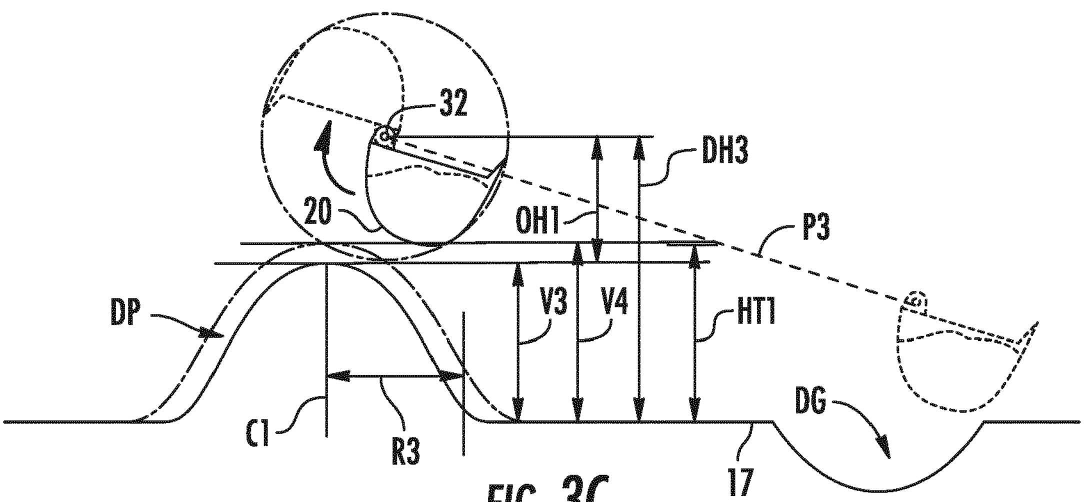

FIG. 3C

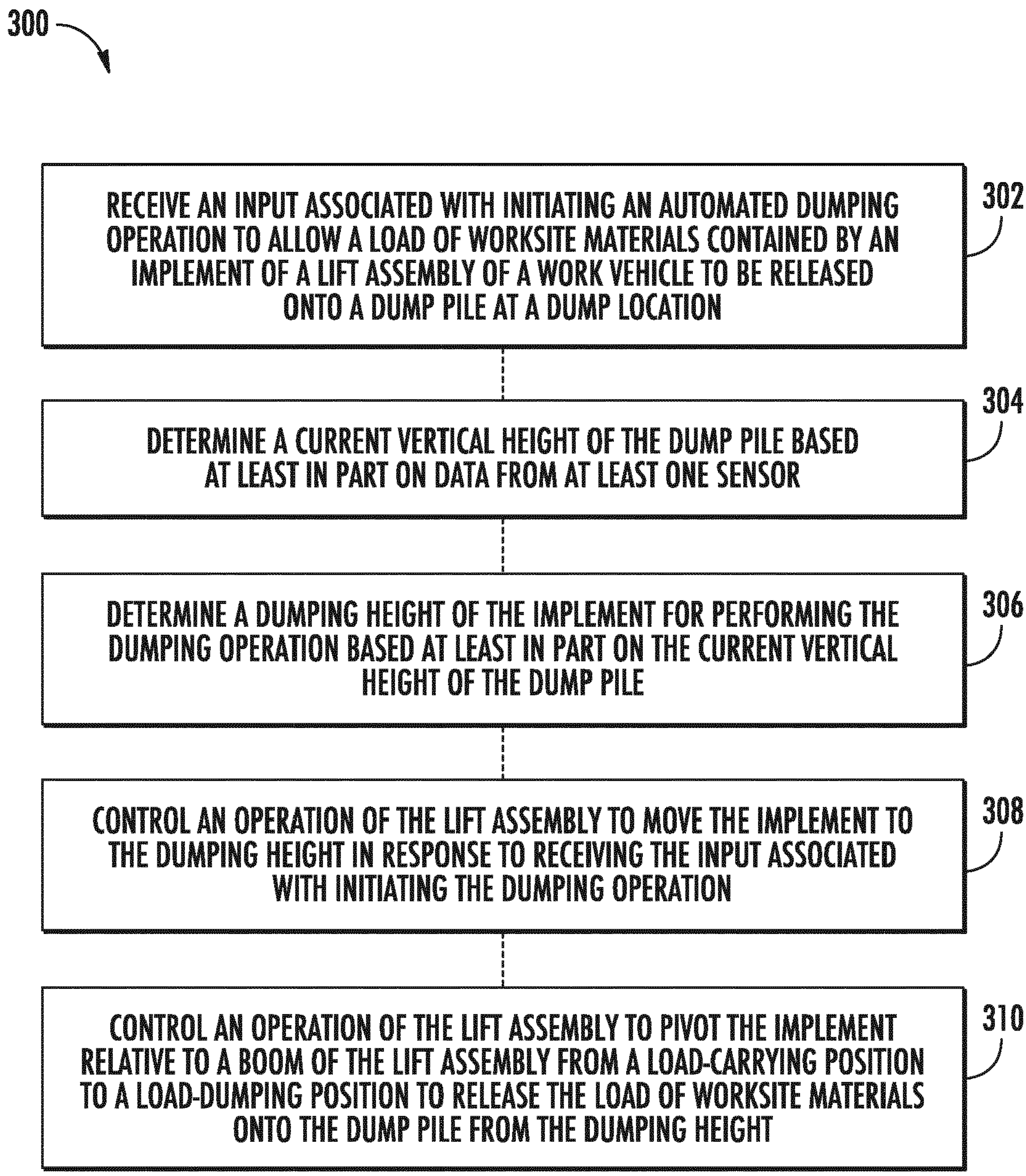
300
RECEIVE AN INPUT ASSOCIATED WITH INITIATING AN AUTOMATED DUMPING OPERATION TO ALLOW A LOAD OF WORKSITE MATERIALS CONTAINED BY AN IMPLEMENT OF A LIFT ASSEMBLY OF A WORK VEHICLE TO BE RELEASED ONTO A DUMP PILE AT A DUMP LOCATION
302
DETERMINE A CURRENT VERTICAL HEIGHT OF THE DUMP PILE BASED AT LEAST IN PART ON DATA FROM AT LEAST ONE SENSOR
304
DETERMINE A DUMPING HEIGHT OF THE IMPLEMENT FOR PERFORMING THE DUMPING OPERATION BASED AT LEAST IN PART ON THE CURRENT VERTICAL HEIGHT OF THE DUMP PILE
306
CONTROL AN OPERATION OF THE LIFT ASSEMBLY TO MOVE THE IMPLEMENT TO THE DUMPING HEIGHT IN RESPONSE TO RECEIVING THE INPUT ASSOCIATED WITH INITIATING THE DUMPING OPERATION
308
CONTROL AN OPERATION OF THE LIFT ASSEMBLY TO PIVOT THE IMPLEMENT RELATIVE TO A BOOM OF THE LIFT ASSEMBLY FROM A LOAD-CARRYING POSITION TO A LOAD-DUMPING POSITION TO RELEASE THE LOAD OF WORKSITE MATERIALS ONTO THE DUMP PILE FROM THE DUMPING HEIGHT
310

FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 22 17 9251

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2020/362530 A1 (SEKI YOHEI [JP] ET AL) 19 November 2020 (2020-11-19) * paragraphs [0022], [0035], [0036], [0038], [0039], [0044], [0051], [0052], [0053], [0060], [0063], [0083], [0084]; figures 1,2,4A-4C,6 * -----	1,3,5, 12-14	INV. E02F3/43 E02F9/26
X	JP 2020 204193 A (KOMATSU MFG CO LTD) 24 December 2020 (2020-12-24) * paragraphs [0019], [0025], [0061], [0080], [0085], [0093], [0105]; figure 2 * -----	1,3,5, 12-14	
A	US 7 276 669 B2 (CATERPILLAR INC [US]) 2 October 2007 (2007-10-02) * column 2, line 55 - column 3, line 67; figures 1-3 * -----	1-15	
A	US 2015/176253 A1 (TAYLOR LANCE [UA] ET AL) 25 June 2015 (2015-06-25) * paragraphs [0049] - [0051] * -----	1-15	TECHNICAL FIELDS SEARCHED (IPC)
			E02F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	22 November 2022	Luta, Dragos

CATEGORY OF CITED DOCUMENTS

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22-11-2022

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